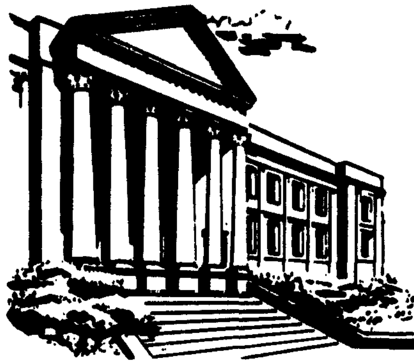

Monthly Progress Report P-B1981-9

DEVELOPMENT OF BROAD-BAND ELECTROMAGNETIC ABSORBERS FOR ELECTROEXPLOSIVE DEVICES

by

Paul F. Mohrbach
Robert F. Wood

March 1, 1963 to March 31, 1963

Prepared for

U.S. NAVAL WEAPONS LABORATORY
Dahlgren, Virginia
Code WHR

Contract No. N178 - 8087

THE FRANKLIN INSTITUTE
LABORATORIES FOR RESEARCH AND DEVELOPMENT
PHILADELPHIA PENNSYLVANIA

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ABSTRACT

Good contact between the mating surfaces of the ferrite toroids and the conductors in a coaxial line is of extreme importance if RF leakage is to be kept to a minimum. We have established that silvering the inner and outer diameters of the toroids is the only answer short of making each ferrite an integral and fixed part of the measuring fixture. Our problem has been the type of silver coating to use. Data are presented on various techniques of electrodepositing silver coatings and on the results obtained.

Attenuation data are given for a special K-24 ferrite toroid sent to us for evaluation. When silverplated it had a resistance of 0.38 ohms. Attenuation values at 1 Mc and 200 Mc were 36 db/cm and 150 db/cm respectively.

It is our experience that high attenuation of RF energy at low frequencies must be paid for in the lowering of the resistivity of the absorbing medium. Attempts thus far to insulate the low resistance, high attenuation samples has not been satisfactory. However, another means to compensate is to just put more length of the absorbing medium in the path of propagation. Our first attempts to show the feasibility of this method were made with carbonyl iron. Attenuating data are presented for this device, and a diagram illustrates its construction.

Work on FIL special attenuators has been delayed because of poor deliveries of the ferrite pieces. However, delivery is promised in the next week so that construction can proceed.

Ferrites of suitable loss characteristics were produced by slow cooling in an inert atmosphere. It was necessary to enclose the furnace to maintain the desired environment. Difficulty was encountered with the ferrites fuzing to the zirconia substrate. Preliminary tests indicated that aluminum oxide or platinum may be satisfactory. An unexplained separation of some component of the ferrite was encountered during one firing run. This phenomenon has not yet been fully studied.

Lossy insulated iron powders were used to insulate ferrite attenuators by a number of methods. The attenuation from the iron insulation did not compensate for the loss in attenuation due to the decrease in conductivity.

Ferrite coatings were fired onto platinum, tantalum, tungsten, and molybdenum conductors in nitrogen at 1400°C for two hours. Only the platinum survived this treatment. The ferrite coating on this 0.020 inch diameter platinum wire had a number of voids which prevented attenuation measurements from being made.

Our first attempt to anodize tantalum wire to form tantalum pentoxide has failed. The power supply used in the experiment was not capable of delivering adequate current. Applying the voltage in increasing steps may be required to overcome this difficulty.

An effort to derive a general-case mathematical model of a two layer coaxial transmission line has been started. We investigated the basic one layer case by computing the values of the zero and first order propagation constants for a wide range of material parameters (the conductors of the line were assumed perfect). Results showed that the T.E.M. (or zero order) propagation constant was overwhelmingly dominant except when very large values of attenuation are indicated by the T.E.M. propagation constant; in this case, the first order attenuation constant approaches the zero order constant.

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1. INTRODUCTION

The Franklin Institute, under contract to the Naval Weapons Laboratory and Picatinny Arsenal, has during the past several years been active in the search for materials which attenuate RF energy. A significant development has been the carbonyl iron attenuating material which provides, in a one centimeter length, adequate protection for frequencies above 100 megacycles. For frequencies in the range of 1 to 10 megacycles, very little attenuation is afforded in a one centimeter length. Since we do not foresee any radical improvement in the carbonyl iron's attenuating ability at low frequencies, we have discontinued its development on this contract. It has therefore become necessary to seek other materials to obtain the desired attenuation at low frequencies.

An ideal material would have the absorption characteristics shown by curve 1 in Figure 1-1. The probability of there being a single material having a step function of this type is remote. Curve 2 would more reasonably represent the actual characteristics; curve 1 is the goal toward which we work.

At the outset, our research indicated that the class of materials known as ferrites show promise, and particularly so if the dielectric and magnetic properties of these materials can be selected for optimum results. Two basic approaches to the problem are being pursued; one is the development of an ideal model that could be used by a ferrite manufacturer to make a specific ferrite; the second approach is the development of ferrites in our own laboratory. We would point out, however, that other types of materials (such as organic compounds) will also be considered.

Concurrently, we are developing techniques and processes to use ferrites in practical applications. This includes the application of a high-K dielectric to the material or to the conductor to improve its dc resistance and voltage breakdown properties. Molding of ferrites into such things as plugs for EED's presents a problem because of the high temperatures involved in sintering the ferrites. Methods of molding plugs around wire conductors without the necessity of heat is being investigated.

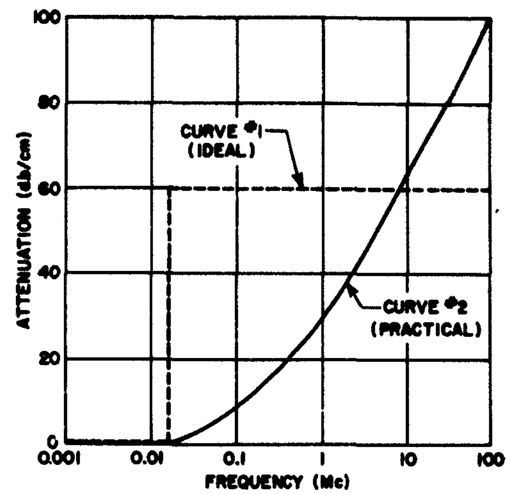

FIG. I-1. IDEAL ATTENUATION CURVE

A supporting instrumentation development program is being conducted concurrently with the materials study. Instrumentation developed to measure attenuation at the frequencies of concern (10 Mc and below) will, in itself be advancing the state of the art. We are interested in true dissipative attenuation; not insertion loss. Since most of our samples are low impedance, this makes matching difficult, and matching has been used in most of our attenuation measuring systems up to now. We have developed two other systems that do not require matching for measuring true attenuation below 10 Mc. These systems are now in the process of being evaluated.

2. MATERIAL STUDY

2.1 Material Evaluation

Contributor: Daniel J. Mullen, Jr.

We are working to find or develop materials which are effective in absorbing RF energy at low frequencies. The present study is concerned with evaluating commercially available ferrites of various types. On the basis of our evaluation, we expect to determine which type shows the most promise. This knowledge will be used to aid in the synthesis of a material as nearly ideal as possible. From this material we will attempt to design RF attenuating devices that will be truly broad-band.

2.1.1 Electrodepositing Techniques and Procedures for Silvering Ferrite Toroids

It has been established in our preceding reports that the contact edges of a toroid must be intimately coated with a good conductor in order that good contact be obtained with the measuring system when the toroid is mounted in a coaxial holder. Our problem has been one of choosing the best coating technique. Early methods included silver paint, air dried/or oven-cured, and epoxy conductive cement also air dried or oven cured. Air dried coatings have not been effective and oven-curing has not improved the coatings very much and has the additional disadvantage of subjecting the ferrites to a temperature of 1200°F, which alters the attenuating properties. We have therefore conducted a series of experiments using electrodepositing techniques. Besides obtaining good silver coatings by these methods, we have also substantiated the various methods reported last month for calculating volume resistivity; validity of data for the calculations depends on good silver coatings.

The following is an account of the treatment of each particular sample:

Silver Plating Solution	Ounces per gallon
Silver Cyanide $AgCN$	4
Potassium Cyanide KCN	7
Potassium Carbonate K_2CO_3	4

pH does not need to be controlled

Sample #6233

Attempted to plate gold directly on surface after KOH wash. Selrex bright gold plating solution was used. The bond of gold to ferrite was very poor.

Sample #6232

Rinse in KOH - light copper plate - gold plate - both plates and acrylic lacquer mask rub off easily.

Sample #6232

Clean off materials left by previous attempt with KOH (hot) - pickle in 50% H_2SO_4 - light nickel plate - light silver plate - light gold plate. Good results.

Sample #6231

Wash in KOH - pickle in 50% H_2SO_4. Five minute nickel plate at 40 ma. Fifteen minutes gold plate at 40 ma. Surface apparently not clean - spotty adhesion of plate - may also be too little nickel.

Sample #6230

Clean with NaOH solution
Pickle with 20% H_2SO_4, 20% HCl — Hot (150°F)

No mask used nickel plate then silver - unwanted silver sanded off after plating - poor method - tears silver.

Sample #6532

No nickel - Krylon mask - Clean with NaOH solution and pickle with 20% H_2SO_4, 20% HCl both at room temperature. Fair plate - some tearing at edges.

Sample #6025 and 6026

These samples were masked with Krylon on their flat faces and were silver plated at 20 ma. The samples required about 15 minutes each to acquire a continuous plate. The samples were not treated in anyway before plating. Good results were obtained.

These plated samples averaged about .003 ohm surface resistance, which is quite good in comparison to painted or cured conductive silver paints. The plating is uniform and shows good adhesion.

2.1.2 Attenuation Measurements of Ferrites

The specially prepared K-24 ferrite sample #6962 was silver plated using the methods as outlined above. The surface resistance was 0.003 ohm and the resistance measured in a coaxial holder was 0.38 ohm. We attempted to measure the attenuation of this sample but because the resistance was so low we were unable to obtain any readings since the attenuation measuring system becomes unreliable for very low resistance samples. We therefore ground the sample to half the original thickness and the resistance was again measured and found to be 2 ohms. This increase in resistance is more than would be expected but it is quite probable that the density is not uniform throughout the length of the piece and thus resistances should vary. Attenuation measurements taken at 1 Mc and 200 Mc were 36 db/cm and 150 db/cm respectively. We are now going to attempt to insulate this sample with a high-K ceramic.

2.1.3 Long Path Devices for Increased Attenuation

We are very concerned with the fact that high conductivity or low resistance seems to be a running mate to high attenuation at low frequencies. Our concern rests mainly with the ratio of the resistance of the attenuating material to the resistance of the majority of EED's. We should like this ratio to be at least 100:1. So far, attempts at insulating ferrites to raise the resistance have not been satisfactory for the attenuation under these conditions has been reduced considerably. While this work is still in progress, we are attacking the problem in another way, that is, by increasing the length of the insulated ferrite in order to recover the attenuation that was lost. In order to prove the feasibility, however, we have begun with carbonyl iron. A special die was designed and fabricated which would mold a carbonyl iron slug (0.192 inch in diameter, by 1 cm long) with a length of #22 copper wire centrally located. Several plugs were molded.

They were silvered to insure good contact and their resistance and attenuation was measured. (See Table 2-1).

Table 2-1

RESISTANCE AND ATTENUATION DATA ON CARBONYL IRON PLUGS

Sample No.	Resistance (ohms)	Attenuation (db) (150 Mc)
1	120 K	11 db
2	90 K	8 db
3	85 K	7.5 db
4	100 K	7.5 db
5	10 K	8 db

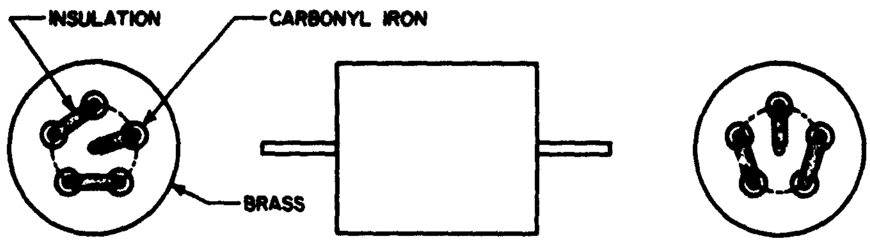

FIG. 2-1. LONG PATH CARBONYL IRON ATTENUATING DEVICE

A coaxial assembly of these plugs was then made, in which all of the leads were connected in series with appropriate insulation and shielding. (See Figure 2-1 for design details). The combined resistance of this assembly was approximately 10,000 ohms and the attenuation measured at 150 mc was 41 db. This shows that we can get the attenuation of a 5 centimeter length of iron in a design length of 1 centimeter by dispersing them in a circular array.

Our next step will be to work with insulated ferrites; these, we hope, work equally well.

2.1.4 FIL Attenuators

Our construction and test of a coaxial attenuator MOD 2 and special twin-lead attenuator MOD 3 has been delayed because of the delay in shipment of the special ferrites which are the heart of the assembly. The supplier has had extreme difficulties in their manufacture and has had to reject the cores several times because of cracks and other defects. Shipment of both the toroids and the twin-lead plugs has been promised for the week of April 1 and work should proceed rapidly upon their receipt.

2.2 Material Evaluation-Tantalum

Contributor: Ernest R. Schneck

In our investigations of RF absorbing materials, we noticed the lossy properties of tantalum capacitors which utilize tantalum pentoxide (Ta_2O_5) as a solid dielectric material and manganese dioxide (MnO_2) as the electrolyte. We are investigating the electrical properties of Ta_2O_5 to determine if this substance is the cause of the attenuation.

2.2.1 Coating Tantalum Wire

We have begun to investigate the dielectric properties of the Ta-Ta_2O_5 conductor, using an oxide-coated tantalum wire as the center conductor of an attenuating doughnut in our transmission line measuring system. We attempted to anodize 50-mil tantalum wire after a method suggested by Vermilyea[(1)]. We selected 100 volts for forming, thus avoiding certain irregularities associated with low or high voltages; 100 volts should afford an oxide thickness of approximately 2000 Å when the coating is formed at approximately 25°C[(2)].

The anodizing solution, 2% HNO_3, formed a low resistance electrolytic cell of approximately 70 ohms. Because the power supply was unable to deliver the required 1.5 amperes, our attempt to anodize failed. We shall make another attempt, starting with much less than 100 volts, to form a preliminary oxide coating, a platinum electrode absorbing the evolved hydrogen. Then we shall increase the resistance of the electrolytic cell, step by step, so that higher voltages can be applied while keeping the current within reasonable limits. Eventually we should be able to form the coating at the desired voltage.

[1].D. A. Vermilyea: Formation of Anodic Oxide Films on Cathodes, J. Electrochemical Soc. 101, 389.

[2].A. F. Torrisi: Relation of Color to Certain Characteristics of Anodic Tantalum Films; J. Electrochemical Soc. 102, 176.

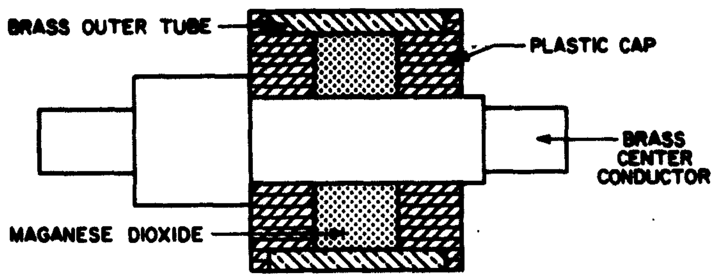

FIG. 2-2. HOLDER FOR WEAK SAMPLES

2.2.2 Measuring Constituents in Bulk

Two of the component materials in lossy tantalum feed-through capacitors were tested in bulk. Manganese dioxide and tantalum pentoxide were pressed in toroidal form with a small amount of binder. The resulting compacts are extremely weak and had to be mounted (actually packed) into a special holder as shown in Figure 2-2. The measured attenuation was negligible for all the samples at 200 Mc; it should be noted, however, that the density was probably rather low.

2.3 Fabrication of Ferrites

Contributor: Joseph F. Heffron

Rapidly cooling the fired ferrites to obtain high conductivity and loss characteristics resulted in rather fragile specimens. We reasoned that slower cooling should increase sample strength, but, even though inert atmospheres were employed, slow cooled samples did not exhibit the desired properties to the required degree. It did not seem reasonable that the ferrite was as insensitive to the firing atmosphere as past experiments indicated. We chose, therefore, to study this condition further .

2.3.1 Effect of Firing Atmosphere

To improve our control over the firing atmosphere the furnace was enclosed in a large polyethylene bag. There is approximately nine inches of clearance between the furnace and the bag on the sides and about twenty-four inches on top. These dimensions vary as the bag is inflated. The inert gas enters the system through a tube inserted through the bag and into the firing chamber. Gas is supplied at a rate of 0.05 to 0.3 cubic feet per minute, depending on the stage of the firing operation. No exhaust vent is provided as there is sufficient leakage to prevent overinflation.

Initially, the system was flushed for several days with argon to remove all air. Several samples were prepared from $Mn_{0.67}$, $Zn_{0.33}$, Fe_2O_4, fired for two hours at 1450°C, and slowly cooled in the argon atmosphere. The resulting ferrites were similar in loss and conductivity to those previously produced by rapid cooling. The experiment was repeated using nitrogen in place of argon and results were the same.

2.3.2 Firing Substrates

The ferrite bodies had in the past been placed on slabs of stabilized zirconia grain for firing. Difficulty was encountered, however, in removing the samples from the zirconia after firing. This condition became worse until the bodies began to fuze firmly to this substrate. A more suitable substrate was therefore sought.

Ferrite samples were fired simultaneously on substrates of platinum, aluminum oxide (Norton Company RA-84), and prefired aluminum silicate. There was no obvious reaction with the platinum, and only very slight reaction with the aluminum oxide. The ferrite did not fuze to the substrate in either case. The aluminum silicate did react with the ferrite and was entirely unsuitable. We chose to use the aluminum oxide for subsequent firings.

A batch of thirty-two samples was then fired on the aluminum oxide substrate with unexpected results. Some component of the ferrite apparently separated from the body and flowed out into the substrate. The remaining material, some of which retained its original shape and some of which did not, is porous and of low density. It is not known whether the material entering the substrate merely permeates it or combines with it chemically. We have not had time to study this phenomena fully, nor have we any explanation for its occurrence.

3. APPLIED STUDIES

3.1 Dielectric Insulators

Contributor: James D. Dunfee

The voltage breakdown and insulation resistance of attenuators may be increased by application of high K dielectric insulating films to the initiator conductors.

Tubular capacitor bodies have been used successfully with carbonyl iron attenuators. A dielectric insulation with a K of 115 or greater, and with a wall thickness of 0.017 inch or less, gave no change in attenuation when applied to carbonyl iron slugs. Use of such preformed dielectrics as insulators with ferrite attenuators has indicated substantial decrease in attenuation, apparently due to decreases in the shunt loss of the low resistance ferrites.

Application of a K = 30 mixture of 85% barium titanate in a liquid acryloid binder to carbonyl iron attenuators has shown a voltage breakdown of 500-600 volts with a 20-25% decrease in attenuation, for a 2 to 3 mil coating of this insulation. Almost all of the attenuation losses of ferrite bodies disappear when this coating is applied to them.

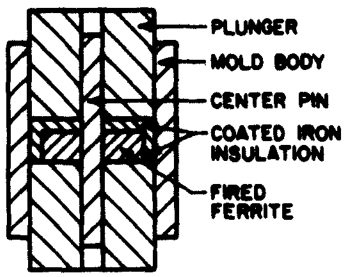

FIG. 3-1. SAMPLE NO. 6031 MOLDING PROCEDURE

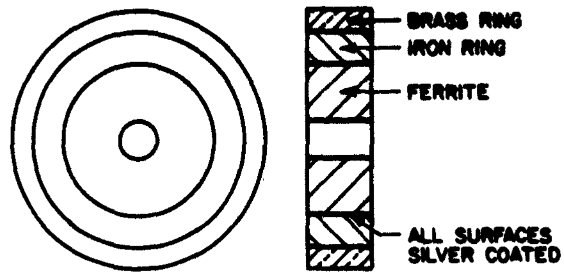

FIG. 3-2. SAMPLE NO. 6513 IRON INSULATED FERRITE

This month a silica coated iron powder mixed with the acryloid binder was applied to stainless steel wires. A dielectric constant close to K = 90 was obtained but the voltage breakdown was less than 30 volts. Some of the coated powder was molded into standard toroids (Sample No. 7105, 7107) and the measured resistance was 5 ohms, indicating that the powder was not fully insulated. (Previous work has shown that this powder can be made into toroids having a resistance of a megohm or more, when properly insulated).

We applied insulated iron powder to ferrite attenuators by several methods. The results are shown in Table 3-1. Sample #6031 was positioned as shown in Figure 3-1 and the insulation compressed on the ferrite. The overall pressure was 85,000 psi, but the sides exhibited low density due to large components of molding friction. Sample #6513 was insulated by boring out a carbonyl iron toroid and cementing it in position on the outside diameter of the ferrite as shown in Figure 3-2.

Since the method of coating wires with insulated powder mixed in acryloid binder has been used with ferrite powders, we attempted to fire ferrite coatings in position on refractory metal conductors.

Platinum, tantalum, tungsten, and molybdenum conductors were coated with a 0.010 to 0.015 inch thick mixture of 90% ferrite (T-1) and 10% binder. The wires were fired in nitrogen at 1400°C for two hours. All of the conductors oxidized except the platinum wire. This wire has what appears to be a ferrite coating on its surface. The small diameter (about 0.020 inch) prevented further tests on this specimen; the ferrite coating also exhibited a number of voids, effectively preventing application of a silver outside conductor. A larger diameter (0.062 inch platinum) has been ordered so that this work might be continued.

Table 3-1

ATTENUATION CHANGE WITH LOSSY IRON INSULATORS

Sample No.	Insulating Coating	Resistance ohms	Attenuation db
6028	Silvered	17	38 at 50 Mc
(C-24)	Sil-Iron-Acryloid (3 Mils)	1800	2 at 50 Mc
6031 (C-27)	Sil-Iron-Molded (30 Mils)	5,000,000	2 at 50 Mc
6513	Silvered	740	31 at 200 Mc
(T-1)	MPD-22 Iron (80 Mils)	180,000	11.5 at 200 Mc

3.2 Coaxial Line Propagation

Contributor: Ramie H. Thompson

In an effort to derive a general mathematical model of the electrical behavior of a good conducting coaxial line filled with two layers of material, we began by investigating the single layer case. The results of this work are reported below. Further work has been started on determining the two-layered propagation constants by solving the appropriate boundary value problem and assuming that the conductors are perfect (i.e, $\sigma = \infty$). The results of this work will be presented in the next report[3]. Another configuration, this one with a thin layer of good conductor between the two other layers, is being investigated under the assumption that the conducting layer is at least as thick as the skin depth. We expect to approach this problem by considering the line as two transmission lines whose inputs and outputs are connected in series, that is, as the series connection of two two-port networks.

3.2.1 Single Material Line

The problem of predicting the propagation constants of a perfectly conducting coaxial line filled with lossless dielectric is treated in the general case by S. A. Schelkunoff[4]. If losses are accounted for by using a complex permeability and permittivity and the coaxial line is assumed to have its outer diameter less than three times its inner diameter then the propagation constants of the lossy line can be approximated by (page 539, reference 4).

$$\Gamma_n = \sqrt{\left(\frac{n\Pi}{g}\right)^2 - \omega^2 \epsilon^* \mu^*} \qquad \text{eq. (3-1)}$$

$$n = 0,1,2\ .\ .\ .$$

where g is the difference between inner and outer radii of the line

ω = 2 Π x frequency

ϵ^* = complex permittivity

μ^* = complex permeability

(3). A special case of this problem is treated in FIL Final Report F-B1857, Naval Weapons Lab. contract N178-7913.

(4). S. A. Schelkunoff, The Electromagnetic Theory of Coaxial Transmission Lines and Cylindrical Shields, The Bell System Tech. Jl. 1934. Vol. 13.

This result is obtained by direct substitution of the complex parameters into Schelkunoff's result. It will be valid as long as the line can be considered a perfect conductor in relationship to the attenuating material.

Equation 1 was computed (n = 0 and n = 1) for all permutations of the values of the parameters shown in Table 3-2 at each of four frequencies (10^5, 10^6, 10^7 and 10^8 cps).

The parameters in Table 1 are related to the ϵ^* and μ^* of Eq. 3-1 as shown below.

$$\epsilon^* = \epsilon - j\frac{\sigma}{\omega} = \left|\epsilon^*\right| \exp\left\{ j \tan^{-1}\left(\frac{-\sigma}{\omega\,\epsilon}\right)\right\} = 1\left|\epsilon^*\right| \exp\left\{ j\,\zeta\,\epsilon \right\}$$

$$\mu^* = \mu - j\frac{\xi}{\omega} = \left|\mu^*\right| \exp\left\{ j \tan^{-1}\left(\frac{-\xi}{\omega\,\mu}\right)\right\} = \left|\mu^*\right| \exp\left\{ j\,\zeta\, m \right\}$$

$$\epsilon_R = \frac{\mathrm{Re}\left\{\epsilon^*\right\}}{\epsilon_o} \qquad\qquad \mu_R = \frac{\mathrm{Re}\left\{\mu^*\right\}}{\mu_o}$$

where σ is the electrical conductivity and ξ is its magnetic analogue. The g used was that of standard 50-ohm coaxial line, 0.159 inch.

The results showed that Re $\{\Gamma_1\}$ was always higher than Re $\{\Gamma_o\}$ for all values of the parameters computed and that Re $\{\Gamma_1\}$ was very much higher than Re $\{\Gamma_o\}$ except for very large values of parameters (i.e. Re $\{\Gamma_1\} >>$ Re $\{\Gamma_o\}$ except when attenuation is very high). We can therefore use the T.E.M. (or Γ_o mode) equations for prediction of propagation phenomena except for very lossy materials. The computed values of Γ_o are also useful as a table of attenuation versus parameter values.

Re $\{\Gamma_1\}$ is read as real part of Γ_1; note that the attenuation of a mode can be expressed by .0867 Re $\{\Gamma\}$ db/cm.

Table 3-2

VALUES OF PARAMETERS FOR WHICH PROPAGATION CONSTANTS WERE COMPUTED

μ_R	ϵ_R	TEM ζ_m	TEM ζ_e
1	1	.001	.001
1001	4001	5.001	2.001
2001	8001	10.001	4.001
3001	12,001		6.001
	10,001		8.001
4001	20,001		10.001

4. INSTRUMENTATION

No work was done on this phase during March.

5. CONCLUSIONS AND FUTURE PLANS

Ferrites

Most of this work during the remainder of the contract will be the incorporation of commerical ferrites and FIL-made ferrites into finished attenuators. We are striving to produce an attenuator that has approximately 30 to 60 db in a four-inch length and a dc resistance greater than several megohms. A minimum voltage breakdown of 300 volts is desired. Two basic types are being considered: coaxial and twin lead.

Results of the study on different methods of depositing a silver coating on a ferrite indicate that the electrodeposition of silver from a silver cyanide solution produces an excellent coating. Surface resistance of approximately 0.003 ohms per inch (measured with a Keithley milliohmmeter) was obtained. Fortunately, electroplating lends itself to mass coating; we are able to coat 25 samples at one time.

It is possible to produce lossy ferrites by cooling them slowly in an inert atmosphere. Oxidation is, apparently, a major factor in determining the conductivity and loss characteristics of this material.

We had hoped to prepare a large number of samples to be incorporated into attenuator assemblies. The separation of the material during the firing of the first large batch has prevented this. We shall strive to eliminate this difficulty and proceed with ferrite production as planned.

Dielectric Coatings

Successful application of a fired ferrite coating on wire could pave the way for the ultimate in long path devices, such as the coiled conductor shown in Figure 5-1. Insulation applied to such a conductor could be less than 100% effective and the assembly would still provide the attenuation wanted in a specified volume.

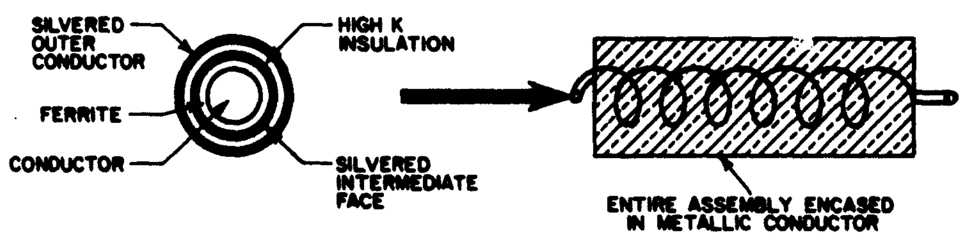

FIG. 5-1. COILED FERRITE-COATED CONDUCTOR AND COAXIAL CROSS SECTION

We have received a reply from the Naval Research Laboratory concerning their processing of cold-cured barium titanate. In essence, the necessity for completely reacted C.P. barium titanate is stressed. We shall continue work on this process when such $BaTiO_3$ is received from the manufacturer.

Work on silica-insulated iron powder lossy insulation will be continued to determine feasibility of such an insulator for use with ferrite attenuators.

Tantalum

Anodizing of a tantalum wire to obtain a coating of tantalum pentoxide will be further investigated. Once this has been done, we will put a coating of silver on the surface and then measure the attenuation of the oxide coating; we will then place a ferrite toroid around this.

Coaxial Line Propagation

Next month we will present the classical boundary value equations that specify the propagation constants in the two-layer model. These will be completely general except for the assumption that the conductors are perfect relative to the two materials making up the layers. We are at present trying to simplify the equations. If time permits, we also wish to investigate another configuration, one in which a thin layer of a good conductor is interposed between the two layers.

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